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(54) Title: **SYSTEM AND METHOD FOR DATA BURST COMMUNICATIONS IN A CDMA NETWORK**

(57) **Abstract:** A method is provided for establishing outer loop power control in the transmission of data bursts in an IS-2000A standard CDMA system. The present invention was developed to address the problems of cell sensitivity and capacity degradation that are inherent in transmission of long messages. The present invention is based on the concept of joint re-transmitted message frame combining to adjust the outer loop setpoint. The inner loop power adjustment during the message transmissions uses the setpoint established by the outer loop function. The outer loop memory spans multiple message transmissions in that the setpoint adjustment during transmission of a message depends both on the adjustment performed during the previous message transmission and on the effective message length. The effective message length is reduced at each transmission attempt by means of the message re-transmission combining function. A system and apparatus which control the outer loop power function in accordance with the above-described method are also provided.

System and Method for Data Burst Communications
in a CDMA Network

Background of the Invention

5 The present invention relates generally to high speed data communications and, more specifically, to a system and method for regulating the uplink power control in a third generation (3G) code division multiple access (CDMA) communications system.

10 The IS-2000 standard for 3G CDMA systems calls for transmission of data bursts uplink from the remote units using a R-CCCH channel, which is defined as a reverse access channel. Because of the length of the message, a data burst transmission must be received with high power, relatively to that of all other users on dedicated channels, e.g., voice users, if a reasonable message error rate is to be achieved. Therefore, the cell receiver sensitivity is degraded during reception of the data burst. For a given message error rate, the cell sensitivity degradation is proportional to the message length, i.e., the 15 number of frames, in the message. A higher cell sensitivity means that all active users must increase their transmit power to close the reverse link. That may not be possible, especially for those users who are located at the cell boundary and already transmitting at nearly full power. Therefore, all the users located at the cell boundary will experience an outage and may drop the connection. In an extreme scenario, that is, for very long 20 messages, the sensitivity degradation is such that the entire population of users in the cell will suffer an outage. The high power data bursts not only momentarily degrade sensitivity, but may also consume reverse link capacity and lead to unstable behavior.

25 In the second generation CDMA systems specified by the IS-95B standard, the problem of cell sensitivity during periods of uplink data bursts was addressed by limiting the message size transmitted on the reverse access channel to a small number of frames, typically 8 or less. The data rate was limited to 4.8 kbps, i.e., inferior to the one used by the users active on the dedicated (voice) channels, which is 9.6 or 14.4 kilobits per second (kbps). Further, the IS-95B access channels are not power controlled, and they are contention based.

30 In IS-2000A a new access channel is defined, the R-CCCH, which permits the transmission of a very long data burst (in excess of 200 frames) at high rate (up to 38.4 kbps). As presently configured, the data burst protocol for IS-2000A CDMA systems is characterized by an assured transmission of a data burst, or message, over a reserved, power-controlled channel of the CDMA system. The data burst consists of multiple 35 frames. In other communication systems, the transmission of the data bursts are made reliable by using transmission repetition protocols such as stop-and-wait or selective

repeat. Due to the protocol overhead, however, the retransmission protocol is implemented at message level rather than at frame level. That is, upon successful message decoding, the base station acknowledges receipt of the entire message, but not of any of its constituent frames. Thus, if any frame of the message was unsuccessfully decoded, the entire message must be retransmitted.

The channel data uplink channel is a reserved, i.e., contention-less, channel. The channel is also power controlled by the base station. The base station transmits a sequence of power control bits to the mobile station over a forward power control channel. The polarity of the power control channel bits indicates either an 'up' or 'down' command.

The base station periodically estimates the received energy of the reverse control channel and transmits an 'up' command if the energy falls below a signal to noise threshold, and transmits a 'down' command otherwise. The mobile station receives the power control bits and adjusts its reverse control channel transmit power accordingly. The function outlined above is usually called inner loop power control, and it is equivalent to the one normally used for the dedicated traffic channel of IS-95B CDMA systems.

The base station re-assembles the message after receipt of the last transmitted frame and, if the message contains no errors as indicated by the error detecting decoder, transmits the mobile station an acknowledgment message over a forward control channel. If the message re-assembly fails, then the base station takes no action.

After completing transmission of the data burst over the reverse control channel, the mobile station waits for the base station acknowledgement. If the acknowledgement is not received within a given amount of time, or if a negative acknowledgment is received, the mobile station repeats transmission of the entire data burst message.

Data bursts are received over the reverse link common control channel (R-CCCH) using the reservation access mode, as specified in IS-2000A. The R-CCCH is a reserved channel. Its framing format includes 5, 10, or 20 msec frames that can be transmitted at 9.6, 19.2, or 38.4 kbps. The R-CCCH is power controlled by a subchannel of the forward common power control channel (F-CPCCH). The procedure to reserve the R-CCCH takes place on a different set of common channels, namely the R-EACH and the F-CACH. The R-CCCH was introduced in IS-2000A because it provides significant advantages with respect to the R-EACH, both in terms of capacity and throughput, especially for longer messages (> 200 msec).

There are some key issues that, unless addressed appropriately, may lead to degradation of both capacity and throughput performance of the data burst protocol over the reserved channel. The first key element consists in the fact that there is no selective retransmission procedure on a frame level. Rather, if one or more frames are received in error, message capsule re-assembly fails and the data burst must be retransmitted entirely.

For longer messages, the data burst signal must be received at a signal to noise ratio that is considerably higher than that required for a dedicated traffic channel operating at the same data rate, where the target frame error rate of the traffic channel is the same as the reserved channel target message error rate. Assuming independence of the received frame erasures, 5 the target message error rate (MER) has a relationship to the frame error rate (FER) that is a function of the message size, where N is the number of frames in the message:

$$MER = 1 - (1 - FER)^N \rightarrow FER = 1 - (1 - MER)^{1/N} \approx \frac{MER}{N}$$

10 The result above indicates that when the message size is equal to 100 frames, for example, the reserved required FER is approximately 100 times smaller than that required for the dedicated channel FER. A required FER ratio equal to 100 corresponds to an increased required signal to noise ratio of 3 to 9 dB, approximately, depending on channel conditions.

15 If the reserved channel sensitivity is much higher than that of the dedicated channels, as in the example above, the data burst transmission will cause a temporary cell sensitivity degradation. That is, the cell maximum path loss (cell size) will shrink by the same amount, possibly causing an outage for all the users near the cell boundaries. Of course, the cell capacity is also momentarily degraded.

20 There is the possibility that future modifications to the IS-2000 standard may permit the base station to communicate to the mobile station information to identify the received and incorrectly received portions of the MS transmission, so as to permit the MS to retransmit only the incorrectly received portions of the original transmission.

25 The second key problem is the selection of the power control inner loop setpoint. The inner loop setpoint required for reliable message detection depends on channel conditions and, as explained above, on the message size, which may not be known a priori to the base station. Without an outer loop function the inner loop setpoint must be set to a conservative value corresponding to the worst case (i.e., to the maximum allowable message size and worst case channel conditions). If the setpoint is set to a value of less than the one corresponding to the worst case, long messages and/or messages transmitted over a poor channel are likely to be retransmitted several times, compromising the 30 throughput and capacity of the common channel. However, when the setpoint is set to a value corresponding to the worst case, considerable capacity is wasted for transmission of any message of length less than the maximum length and/or messages transmitted over a favorable channel.

35 The considerations above clearly demonstrate the advantages that an outer loop function can provide. The outer loop function should function to adjust the required inner loop setpoint and so achieve the desired MER with the least possible capacity

consumption. Conventional outer loop functions, such as the one used for the dedicated channels, are driven by frame erasures or, more generally, by some quality metric of the received frame. That is, they are driven by some small acceptable error rate in an attempt to set the MS transmit power as the lowest possible level to support communications.

5 However, this conventional outer loop function, based on an acceptable error rate, cannot be applied to the burst transmission over reserved channels because a single frame received in error will cause the message to be discarded, and require the mobile station's re-transmission of the entire message.

It would be advantageous if an IS-2000A standard R-CCCH could be operated to
10 support long messages at high data rates without degrading cell sensitivity.

It would be advantageous if other communication system parameters could be modified to permit high data rates without sacrificing cell sensitivity. For example, if message transmission latency could be traded for cell sensitivity.

15 It would be advantageous if optimal FER and MER could be established for data burst transmissions without causing entire messages to be discarded because of erased frames.

It would be advantageous if outer loop power controls could be established for 3G CDMA data burst transmissions to limit cell sensitivity degradation. It would be
20 advantageous if an outer loop power control could be established to regulate a signal to noise threshold. Then, the inner loop power control could be maintained using the threshold established with outer loop controls.

Summary of the Invention

Accordingly, a method is provided for receiving bursts of data in a CDMA communication system. The method comprises: receiving information as data frames at a
25 first transmitted power level; saving correctly received frames; selecting a second power level in response to correctly received frame; and receiving the information at the second transmitted power level. The process of receiving information is typically iterative as the information is retransmitted, correctly received frames are saved, and the second power level reselected until all the frames are correctly received, or permission to transmit is
30 revoked.

The method includes: measuring the number of n frames in the information stream and comparing the number of n frames to the number of k saved frames; finding the effective message length of m frames remaining to be received, where $m = (n - k)$; and decreasing the second power level as the number of m frames decreases. More
35 particularly, the threshold used to maintain the inner loop power control is decreased.

Specifically, the n frames of information are considered a message, and the selection of the second power level further includes:

selecting a target message error rate (MER);

calculating the target frame error rate (FER) in response to the MER and the effective message length;

calculating a target signal to noise (S/N) threshold in response to the FER. The outer loop power control maintains a target S/N that is responsive to the effective message length.

The inner loop power control is maintained as follows:

measuring the S/N of the received information;

comparing the measured S/N to the target S/N; and

calculating the second power level in response to the S/N comparison.

A CDMA system for communicating bursts of data is also provided. The system comprises a base station (BS) receiving information as a plurality of data frames transmitted at a first power level. The BS saves correctly received data frames and calculates a second power level in response to correctly received data frames. Then, the BS transmits a second power level signal representing the second power level. A mobile station (MS) transmits the information to the BS. The MS receives the second power level signal from the BS and, in response, transmits the information at the second power level.

The BS includes a cache for saving correctly received frames. The BS adds correctly received frames to the cache that are not already saved, and reselects the second power level in response to the accumulation of correctly saved frames in the frame cache. The BS finds the effective message length of m frames remaining to be received, and decreases the second power level as the number of m frames decreases. The BS maintained outer loop power control by selecting a target message error rate (MER), calculating the target frame error rate (FER) in response to the MER and the effective message length m , and calculating a target signal to noise (S/N) threshold in response to the FER.

The BS maintains the inner loop power control by measuring the S/N of the received information, comparing the measured S/N to the target S/N, and calculating the second power level in response to the S/N comparison.

Brief Description of the Drawings

Fig. 1 is a schematic block diagram of the present invention code division multiple access (CDMA) system for communicating bursts of data.

Fig. 2 illustrates a fundamental application of the present invention power loop correction concept.

Fig. 3 illustrates the concept of effective message length through frame recombination.

Fig. 4a illustrates one embodiment of the present invention outer loop power control.

5 Fig. 4b illustrates another embodiment of the present invention outer loop power control.

Figs. 5a and 5b are flowcharts illustrating a method for receiving bursts of data.

Fig. 6 is a flowchart illustrating a method for transmitting bursts of data.

Detailed Description of the Preferred Embodiment

10 The present invention was developed to address the cell sensitivity problems resulting from the use of data bursts, discussed in the Background Section above. The present invention is based on joint retransmitted message frame combining, and outer loop setpoint adjustment. The inner loop setpoint is responsive to the outer loop function and also more simply, to whether the previous frame was correctly received. The outer loop 15 memory spans multiple message transmissions in that the setpoint adjustment during transmission of a message depends both on the adjustment performed during the previous message transmission and on the effective message length. The effective message length is reduced at each transmission attempt by means of the message re-transmission combining function.

20 The initial setpoint is selected based on, for example, the expected message length and target MER. While receiving the message, the R-CCCH outer loop adjusts the setpoint based on quality indicators of the received frame. While the R-CCCH is typically mentioned herein as the channel used to control power, it is understood that any reverse common channel could be used to perform the same function. If an erasure is received, the 25 setpoint is increased. If a good frame is received, the base station stores the good frame and decreases the setpoint. Setpoint increase and decrease values are selected based on the FER target, as for the dedicated traffic channel outer loop power control. In the event that frames are received in error, the mobile station will repeat the transmission. The base station must detect that the mobile station is retransmitting the data burst. The new 30 setpoint is set to the one corresponding to the last frame of the previous message transmission, possibly adjusted to account for the FER estimated in the previous message transmission, or for the message length, or a combination of both. The base station combines the good frames accumulated in all previous transmissions together with those received in the current transmission and attempt message re-assembly.

35 Fig. 1 is a schematic block diagram of the present invention code division multiple access (CDMA) system for communicating bursts of data. The system 10 comprises a

first, receiving station 12 having a port on line 14 to receive a first information stream including a plurality of data frames transmitted at a first power level. The first station saves the correctly received data frames from the first information stream and calculates a second power level in response to correctly received data frames.

5 The first station 12 includes a receiver 16 connected to the port on line 14 to receive the first information stream. The first station 12 includes a cache 18 for saving correctly received frames. The first station 12 adds correctly received frames to the cache 18 that are not already saved in the cache 18. A controller 20 selects a second power level in response to the number of correctly received data frames, and a transmitter 22, 10 connected to the port on line 14, transmits a second power level, or power control signal representing the value of the second power level. The controller 20 selects the second power level in response to the accumulation of correctly received frames saved in the frame cache 18.

15 A second, transmitting station 24 has a port on line 26 to transmit and receive messages. A transmitter 28 is connected to the port on line 26 to transmit the first information stream including a plurality of data frames at the first power level. A receiver 30 is connected to the port on line 26 to receive the second power level signal in response to the number of correctly communicated first information stream data frames. The transmitter transmits the first information stream at the second power level in response to 20 receiving the second power level signal.

Typically, the first station 12 is a base station and the second station 24 is a mobile unit. However, in some aspects of the invention the first station 12 is a mobile unit and the second station 24 is a base station.

25 The second power level is constantly adjusted until the information stream is correctly received. Outer loop power control is one of the variables driving the adjustment of the second power level. The first station receiver 16 iteratively receives the first information stream, the first station controller 20 iteratively reselects a second power level in response to the number of correctly received frames, and the first station transmitter 22 iteratively transmits a reselected second power level signal in response to the reselected 30 second power levels. Likewise, the second station transmitter 28 iteratively transmits the first information stream at the second power level selected by the first station 12.

35 Fig. 2 illustrates a fundamental application of the present invention power loop correction concept. In Step 1, the second station uses a reverse link common channel to notify the first station that it has a data burst to uplink, and to reserve a channel for the transmission. The first station assigns a channel to the second station with the use of the forward common channel in Step 2. In Step 3, the first station uses a forward common power control channel to transmit an initial, or first power level signal, as is discussed in

more detail below, which represent a power level the second station will use. In Step 4 the second station transmits the first information stream at the first power level. In Step 5 the first station transmits a second power level signal, and in Step 6 the second station transmits the first information stream at the second power level.

5 Returning to Fig. 1, the first station receiver 16 measures the number of n frames in the first information stream. The first station controller 20 compares the number of n frames in the first information stream to the number of k correctly received frames saved in the cache 18. The first station controller 20 finds the effective message length of m frames remaining to be received, where $m = (n - k)$, and decreases the second power level
10 as the number of m frames decreases. Alternately, the effective message length can be calculated by a comparison to the number of incorrectly received frames to n .

15 Fig. 3 illustrates the concept of effective message length through frame recombination. In the first transmission, the second station 24 transmits the first information stream of n frames. The first station 12 correctly receives Frame 2, depicted with solid lines. Portions of other frames, such as Frames 1 and n , depicted with dotted lines, may have also been received, but enough of the frame was missed that recovery was impossible. Before transmission the message length was n . Since Frame 2 was correctly received and saved, Frame 2 is added to the cache and the effective message length after the first transmission is $(n - 1)$. Frame 1 was correctly received after the second transmission
20 so it is added to cache and the effective message length becomes $(n - 2)$. In the third transmission two frames, Frames 1 and n are correctly received. However, since Frame 1 is already stored in memory, only Frame n is added to cache and the effective message length is only reduced by one frame.

25 Returning to Fig. 1, the second station 24 transmission of the first information stream of n frames is considered a message. The first station controller 20 selects a target message error rate (MER), calculates a target frame error rate (FER) in response to the MER and the effective message length m , and calculates a target signal to noise (S/N) threshold in response to the FER. In this manner, the outer loop power control establishes a threshold S/N for inner loop power adjustments.

30 There are different mechanisms which operate to modify the target S/N. The target S/N is modified after the receipt of each frame. If the frame was received correctly (regardless of whether the frame is already in cache) the target S/N threshold is lowered. Likewise, if a frame erasure was received, the target S/N threshold is increased. These modifications permit a system response to increases in noise and interference levels, or to
35 fading or signal amplitude changes due to movement of the second station. In some aspects of the invention the target S/N threshold is recalculated for effective message length at the end of the receipt of the first message stream, and before the information is

retransmitted. In other aspects of the invention the target S/N ratio is modified in response to effective message length on a frame-by-frame basis. In this aspect, the S/N threshold can be lowered in response to the previous frame being correctly received *and* for that frame being saved (as the effective message length is decreased).

5 Alternately stated, the outer loop power control response to the effective message length is variably adjustable. In one aspect of the invention the effective message length is only updated after the complete transmission of the first information stream by the second station 24. In other aspects of the invention, the loop response is quicker. At the other loop speed extreme, the target S/N is updated after the reception of each frame by the first
10 station 12.

Because of the inefficiencies of retransmitting the entire uplink data burst of n frames, it is envisioned that the system may incorporate selective message retransmissions. In this scenario, the first station 12 particularly identifies which of the m frames from the first message stream of n frames have not been saved in cache 18. The first station
15 transmitter 22 transmits a signal which communicates the identity of the m frames not saved. Alternately, the identity of the k saved frames can be communicated. The second station receiver 30 receives the signal and the second station transmitter transmits the first information, which consists of the m frames that have not been saved. That is, only the unsaved frames are retransmitted. The first station receiver 16 receives the first stream of
20 information at the second power level which consists of the m frames that have not been saved.

The recombination concept of the present invention applies equally well when only the unsaved frames are retransmitted, as the effective message length of the transmission remains m frames long. Alternately stated, regardless of whether the entire message of n frames is transmitted, or only the m unsaved frames are retransmitted, the effective
25 message length remains m frames long, and the outer loop calculations, dependent on the effective message length, remain the same.

The operation of the inner power control loop is dependent upon the target S/N threshold established by the outer loop control. The first station receiver 16 measures the
30 S/N of the first information stream and compares the measured S/N to the target S/N. Alternately, the comparison is done with other first station circuitry. The controller 20 calculates the second power level in response to the S/N comparison. The first station receiver 16 iteratively compares the measured S/N to the target S/N, the first station controller 20 iteratively adjusts the second power level in response, and the first station
35 transmitter 22 iteratively transmits the adjusted second power level signal. The second station 24 iteratively adjusts the second power level in response to receiving the adjusted second power level signal.

Likewise, the second station receiver 30 iteratively receives power level signals to reselect the second power level in response to the number of correctly communicated frames, and the transmitter 28 iteratively transmits the first information stream at a reselected second power level. In some aspects of the invention, once the first station 12 5 has received all n frames correctly, the first station 12 transmits an acknowledgment that the n frames have been received.

The second station transmitter 28 transmits a first information stream of consecutive frames including a first frame followed by a second frame. The first station receiver 16 correctly receives the first frame transmitted at the first power level and saves 10 it in cache 18. The first station controller 20 selects a second power level, and the first station transmitter 22 transmits a second power level signal in response to saving the first frame. The second station receiver 30 receives the second power level signal. The second station transmitter 28 transmits the second frame of the first information stream at the second transmitted power level in response to receiving the second power level signal, and 15 the first station receiver 16 receives the second frame of the first information stream at the second transmitted power level.

Initially, the first station controller 20 estimates the number of frames in the first information stream, and selects the first power level in response to the estimated message length, in the same manner as described above for the selection of the second power level. 20 The first station transmitter 22 transmits a first power level signal to the second station 24. The second station 24 transmits the first information stream at the first power level in response to receiving the first power level signal, and the first station receiver 16 receives the first information stream at the first power level in response to the first power level signal being transmitted.

25 The base station sets n_0 equal to the number of frames contained in the message capsule, n , if known. If n is not known a priori, then the base station will set n_0 equal to a predefined value, e.g., the expected (average) message length. The base station selects the target message error rate, MER_0 and computes the target frame error rate, FER_0 , as $FER_0 = 1 - (1 - MER_0)^{1/n_0}$. Finally, the initial inner loop setpoint is computed as 30 $\eta_0(0) = \eta(FER_0)$. η is an empirical function, which may depend on the estimated channel conditions and mobile station speed.

Fig. 4a illustrates one embodiment of the present invention outer loop power control. An initial S/N target threshold $\eta_0(0)$ is calculated based on a target FER, which is dependent on the message length. The initial threshold uses either a known or estimated 35 message length. In this scenario the message length is six frames ($m = n = 6$). The first frame of the first transmission is received correctly and the S/N threshold is reduced a fixed step size. Likewise, the second frame is received correctly and the threshold is

reduced a fixed amount. The third frame is not received correctly and the S/N threshold is increased a fixed step size. Typically, the step size up is larger than the step size down. In some aspects of the invention the target FER has a 1% error rate, so that the up step size is 99 greater than the down step size.

5 At the end of the first transmission four frames have been received correctly. The effective message length becomes two frames. The FER associated with a message length of two frames ($FER_{1,1}$) is lower than the initial FER. As a result the initial S/N threshold at the beginning of the second transmission ($\eta_1(0)$) is considerably lower than $\eta_0(0)$. The S/N threshold varies in fixed steps sizes from the initial starting point at the beginning of 10 the transmission in response to whether a frame was correctly received or not.

15 Fig. 4b illustrates another embodiment of the present invention outer loop power control. An initial S/N target threshold $\eta_0(0)$ is calculated based on a target FER, which is dependent on the message length. The initial threshold uses either a known or estimated message length. Again, the message length is six frames ($m = n = 6$). The first frame of the first transmission is received correctly and the S/N threshold is reduced, but the step size is not fixed. In fact, the step size calculation involves a fixed portion (η_{DOWN}), because 20 the previous frame was received correctly, and a variable portion ($\eta(FER_{0,0}) - \eta(FER_{0,1})$) because the effective message length was reduced. The fixed portion of the step size is similar to the fixed step size described above in the explanation of Fig. 4a.

25 Likewise, the second frame is received correctly and the threshold is reduced. The variable portion of the step size has increased as the effective message length gets smaller. Note that the invention need not necessarily decrease the step in a nonlinear way as the effective message length decreases, but such a formulation promotes a minimal degradation of cell sensitivity. Frame 3 is incorrectly received and the S/N threshold increases a fixed step size, as explained in Fig. 4a, the effective message length remains the same.

30 At the end of the first transmission four frames have been received correctly. The effective message length becomes two frames. Since the S/N threshold is recalculated after the receipt of each frame, there is a much smaller difference in the change of the S/N threshold at the start of the second transmission than was observed in the embodiment of Fig. 4a. The S/N threshold varies in fixed steps sizes from the initial starting point at the beginning of the transmission in response to the first two frames not being received. The S/N threshold is reduced sharply after the receipt of the third frame. Note, however, that 35 the S/N threshold is only reduced a small amount after the receipt of the fourth frame. This is because the effective message length does not change, as Frame 4 was received in the first transmission. Alternately stated, $\eta(FER_{1,3}) = \eta(FER_{1,4})$ so that only the fixed portion of the step size remains.

A comparison of the embodiments of Figs. 4a and 4b shows that the S/N threshold more closely tracks the receipt of correct frames when the effective message length is recalculated after each frame. A lower overall threshold setting results in lower overall transmit power levels which means that cell sensitivity degradation is reduced and uplink 5 capacity is increased.

Regardless of embodiment, inner loop power corrections can be applied, as is well known in the art, once the S/N thresholds have been established. The first station measures the S/N of the received first message to make inner loop power corrections. The first station compares the measured S/N to the target S/N determined by the open loop. In 10 response to the comparisons, the first station sends signals to either raise or lower the transmit power level to obtain the target S/N.

Note that after the first message transmission attempt the message length, in case it was not known a priori, can be reliably estimated. For example, the instant when receiver demodulating element goes out of lock is a reliable indication that the mobile 15 station has terminated message transmission. Since the base station scheduled the start time of message transmission, the base station can compute the message capsule duration, and consequently its size n .

Note that MER_K can be set equal to MER_{K-1} , or it can be set based on residual 20 capacity considerations. In one embodiment of this invention MER_K can be computed recursively, as follows:

$MER_K = \alpha \cdot MER_{K-1} = \alpha^K \cdot MER_0$, with $\alpha \leq 1$. Note also that in this case the FER_K can be obtained recursively using the following approximation:

$$FER_K = \frac{MER_K}{MER_{K-1}} \cdot \frac{n_{K-1}}{n_K} \cdot FER_{K-1} = \alpha \cdot \frac{n_{K-1}}{n_K} \cdot FER_{K-1}$$

If the system is operating under light load and the message latency requirements 25 are stringent, it may be desirable to select a lower value of MER_0 and a value of α closer to unity. On the other hand, if the system is operating under heavy load and capacity is a premium, MER_0 could be set to a relatively large value and decrease the value of α . In doing so, the R-CCCH sensitivity for the first transmission attempt is greatly reduced, while the average message latency is controlled by the setting of α .

30 Fig. 5a and 5b are flowcharts illustrating a method for receiving bursts of data. Although the method is presented as a sequence of numbered steps for clarity, no order should be inferred from the numbering unless explicitly stated. Step 100 starts with a code division multiplexed access (CDMA) system. Step 102 receives a first information stream including a plurality of data frames. Initially, the first information stream is received at a 35 first transmitted power level. Step 104 selects a second power level in response to

correctly received frames. Step 106 is a product where the first information stream is received at the second transmitted power level.

Typically, a further step, Step 103, saves correctly received frames. Then, the second power level selection in Step 104 is responsive to the number of saved frames.

5 Some aspects of the invention comprise iteratively receiving the first information stream, including correctly received frames in Step 102, iteratively saving correctly received frames in Steps 103 and 104, and iteratively reselecting a second power level in Step 104. Step 105 transmits a power control, or power level signal which communicates the selected second power level.

10 In some aspects of the invention the saving of correctly received frames in Step 103 includes sub-steps. Step 103a maintains a cache of the correctly received frames. Step 103b adds correctly received frames to the cache, not already saved in the cache. Then, the second power level is reselected in Step 104 in response to the accumulation of correct frames in the frame cache.

15 In some aspects of the invention the selection of the second power level in Step 104 includes sub-steps. Step 104a measures the number of n frames in the first information stream. Step 104b compares the number of n frames in the first information stream to the number of k saved frames. Step 104c finds the effective message length of m frames remaining to be received, where $m = (n - k)$. Step 104d decreases the second power

20 level as the number of m frames decreases.

Typically, the first information stream of frames is a message, and the first stream of information is received in Step 102 as a signal with respect to a noise floor. Then, the selection of the second power level includes further sub-steps. Step 104e selects a target message error rate (MER). Step 104f calculates a target frame error rate (FER) in response 25 to the MER and the effective message length. Step 104g calculates a target signal to noise (S/N) threshold in response to the FER. Step 104h measures the S/N of the first information stream. Step 104i compares the measured S/N to the target S/N, and Step 104j calculates the second power level in response to the S/N comparison.

As explained above, in some aspects of the invention Step 104g modifies the target 30 S/N threshold on a frame-by-frame basis, so that the threshold increases after a frame erasure, and decreases after a correctly received frame. In other aspects of the invention Step 104g also includes the modification of the target S/N in response to whether the previous frame was saved in cache.

In some aspects of the invention the calculation of the effective message length in 35 Step 104c includes particularly identifying each of the m frames not saved. Alternately, the k saved frames could be particularly identified. Then, the transmission of the second power level signal in Step 105 includes transmitting a signal which communicates the

identity of the in frames not saved. The signal can be also be transmitted on an alternate forward channel communication. Then, the receiving of the first stream of information at the second power level in Step 102 includes receiving a first information stream consisting of (only) the m frames not saved.

5 Some aspects of the invention further comprise iteratively comparing the measured S/N to the target S/N in Step 104h. In response to iteratively comparing the measured and target S/N in Step 104i, Step 104j iteratively adjusts the second power level.

10 Preceding the reception of the first information stream at the first power level in Step 102, Step 101a estimates the number of n frames in the first information stream. Step 101b calculates the first power level in response to the estimation of n frames, and Step 101c transmits a power control signal which communicates the first power level.

15 In some aspects of the invention the reception of the first information stream in Step 102 includes receiving a message of consecutive frames including a first frame followed by a second frame. Step 103 includes the first frame in the first information stream being correctly received at the first transmitted power level and saved. The second power level is selected in response to saving the first frame in Step 104. Then, the second frame of the first information stream is received at the second transmitted power level in Step 102.

20 Fig. 6 is a flowchart illustrating a method for transmitting bursts of data. Step 200 starts with a code division multiple access (CDMA) system. Step 202 transmits a first information stream including a plurality of data frames at a first power level. Step 204 receives a signal which communicates a selected second power level. Step 206 is a product where, in response to the number of correctly communicated data frames, the first information stream is transmitted at the selected second power level. The method 25 comprises iteratively transmitting the first information stream at a reselected second power level in Step 206.

As in Figs. 5a and 5b, the transmission of the first information stream in Step 206 includes: the plurality of data frames in the first information stream being a message; the first information stream being transmitted at a target message error rate (MER); the first information stream being measured for the successfully communicated frames; and the first information stream being transmitted at a target frame error rate (FER) in response to the MER and the number of frames successfully communicated. Then, Step 204 includes the selected second power level being responsive to the target FER.

30 In some aspects of the invention the transmission of the first information stream in Step 202 includes transmitting a message of consecutive frames including a first frame followed by a second frame, with the first frame in the first information stream being transmitted at the first power level. The second power level is selected in response to the

successful communication of the first frame in Step 204, and the second frame of the first information stream is transmitted at the second transmitted power level in Step 206.

In some aspects of the invention the receiving of the power level signal in Step 204 includes receiving a signal which particularly identifies the frames in the first information stream that were not correctly communicated. Then, the transmission of the first information stream at the second power level in Step 206 includes transmitting only the frames that were not correctly communicated.

A system and method have been provided which demonstrate the operation of inner and outer loop power controls which efficiently permit the transmission of long bursts of data in a CDMA. The system recombines frames to "shorten" the message, and latency is traded to preserve cell sensitivity. Other variations and embodiments of these concepts, beyond the exemplary embodiment described above, will occur to those skilled in the art.

Claims

1. In a code division multiplexed access (CDMA) system, a method for receiving bursts of data, the method comprising:

5 receiving a first information stream including a plurality of data frames at a first transmitted power level;

selecting a second power level in response to correctly received frames; and receiving the first information stream at the second transmitted power level.

2. The method of claim 1 further comprising:

saving correctly received frames; and

10 in which the second power level is selected in response to the number of saved frames.

3. The method of claim 2 further comprising:

iteratively receiving the first information stream, receiving correct frames, and reselecting a second power level.

15 4. The method of claim 3 in which the saving of correctly received frames includes:

maintaining a cache of the correctly received frames;

adding correctly received frames to the cache, not already saved in the cache; and

20 in which the second power level is reselected in response to the accumulation of correct frames in the frame cache.

5. The method of claim 2 in which the selection of the second power level includes:

measuring the number of n frames in the first information stream; and

25 comparing the number of n frames in the first information stream to the number of k saved frames.

6. The method of claim 5 in which the selection of the second power level includes:

finding the effective message length of m frames remaining to be received, where $m = (n - k)$; and

30 decreasing the second power level as the number of m frames decreases.

7. The method of claim 6 in which the first information stream of n frames is a message, and in which the first stream of information is received as a signal with respect to a noise floor;

in which the selection of the second power level further includes:

5 selecting a target message error rate (MER);
calculating a target frame error rate (FER) in response to the MER and the effective message length; and
calculating a target signal to noise (S/N) threshold in response to the FER.

8. The method of claim 7 further comprising:

10 following the calculation of the target S/N, modifying the target S/N in response to whether the previous frame was correctly received.

9. The method of claim 7 further comprising:

following the calculation of the target S/N, modifying the target S/N in response to whether the previous frame was saved.

15 10. The method of claim 7 further comprising:

particularly identifying each of the m frames not saved;
transmitting a signal which communicates the identity of the m frames not saved;
and

20 in which the receiving of the first stream of information at the second power level includes receiving the first stream of information consisting of the m frames not saved.

11. The method of claim 7 further comprising:

measuring the S/N of the first information stream;
comparing the measured S/N to the target S/N; and
calculating the second power level in response to the S/N comparison.

25 12. The method of claim 11 further comprising:

iteratively comparing the measured S/N to the target S/N; and
in response to iteratively comparing the measured and target S/N, iteratively
adjusting the second power level.

13. The method of claim 1 further comprising:

30 transmitting a power control signal which communicates the selected second power level.

14. The method of claim 1 further comprising:
preceding the reception of the first information stream at the first power level,
estimating the number of n frames in the first information stream;

5 calculating the first power level in response to the estimation of n frames; and
transmitting a power control signal which communicates the first power level.

15. The method of claim 1 in which the reception of the first information stream includes receiving a message of consecutive frames including a first frame followed by a second frame;

10 in which the first frame in the first information stream is correctly received at the first transmitted power level;

in which the second power level is selected in response to correctly receiving the first frame; and

in which the second frame of the first information stream is received at the second transmitted power level.

15 16. In a code division multiple access (CDMA) system, a method for transmitting bursts of data, the method comprising:

transmitting a first information stream including a plurality of data frames at a first power level; and

20 in response to the number of correctly communicated data frames, transmitting the first information stream at a selected second power level.

17. The method of claim 16 further comprising:

iteratively transmitting the first information stream at a reselected second power levels.

18. The method of claim 16 further comprising:

25 receiving a power control signal which communicates the selected second power level.

19. The method of claim 18 in which transmission of the first information stream further includes:

the plurality of data frames in the first information stream being a message;

30 the first information stream being communicated at a target message error rate (MER);

the first information stream being measured with respect to the number of successfully communicated frames;

the first information stream being transmitted at a target frame error rate (FER), in response to the MER and the number of frames successfully communicated; and

5 in which the selected second power level is responsive to the target FER.

20. The method of claim 17 in which the transmission of the first information stream includes transmitting a message of consecutive frames including a first frame followed by a second frame;

10 in which the first frame in the first information stream is transmitted at the first power level;

in which the second power level is selected in response to the successful communication of the first frame; and

in which the second frame of the first information stream is transmitted at the second transmitted power level.

15 21. The method of claim 18 further comprising:

receiving a signal which particularly identifies the frames in the first information stream that were not correctly communicated; and

in which the transmission of the first information stream at the second power level includes transmitting only the frames that were not correctly communicated.

20 22. A code division multiple access (CDMA) system for communicating bursts of data, the system comprising:

a first station having a port to receive a first information stream including a plurality of data frames transmitted at a first power level, the first station saving the correctly received data frames from the first information stream and calculating a second power level in response to receiving frames correctly, the first station transmitting a second power level signal representing the second power level; and

25 a second station having a port to transmit the first information stream, the second station receiving the second power level signal from the first station and in response, transmitting the first stream of information at the second power level.

30 23. The system of claim 22 in which the first station iteratively receives the first information stream, correctly receives frames, and reselects a second power level; and

in which the second station iteratively transmits the first information stream at the second power level selected by the first station.

24. The system of claim 23 in which the first station includes a cache for saving correctly received frames, with the first station adding correctly received frames to the cache that are not already saved in the cache, the first station reselecting the second power level in response to the accumulation of correct frames saved in the frame cache.

5 25. The system of claim 24 in which the first station measures the number of n frames in the first information stream, and compares the number of n frames in the first information stream to the number of k correctly received frames saved in the cache.

10 26. The system of claim 25 in which the first station finds the effective message length of in frames remaining to be received, where $m = (n - k)$, and decreases the second power level as the number of m frames decreases.

27. The system of claim 26 in which the second station's transmission of the first information stream of n frames is a message; and

15 in which the first station selects a target message error rate (MER), the first station calculating the target frame error rate (FER) in response to the MER and the effective message length in, and calculating a target signal to noise (S/N) threshold in response to the FER.

28. The system of claim 27 in which the first station, following the calculation of the target S/N, modifies the target S/N in response to whether the previous frame was correctly received.

20 29. The system of claim 27 in which the first station, following the calculation of the target S/N, modifies the target S/N in response to whether the previous frame was saved.

30. The system of claim 27 in which the first station particularly identifies the in unsaved frames, and transmits the identity of the in frames to the second station; and

25 in which the second station transmits a first information stream, consisting of the in identified frames, at the second power level.

31. The system of claim 27 in which the first station measures the S/N of the first information stream, compares the measured S/N to the target S/N, and calculates the second power level in response to the S/N comparison.

32. The system of claim 31 in which the first station iteratively compares the measured S/N to the target S/N, iteratively adjusts the second power level in response, and iteratively transmits the adjusted second power level signal; and

5 in which the second station iteratively adjusts the second power level in response to receiving the adjusted second power level signal.

33. The system of claim 22 in which the first station estimates the number of frames in the first information stream, selects the first power level in response to the estimated message length, and transmits a first power level signal to the second station; and

10 in which the second station transmits the first information stream at the first power level in response to receiving the first power level signal.

34. The system of claim 22 in which the second station transmits a first information stream of consecutive frames including a first frame followed by a second frame;

15 in which the first station correctly receives the first frame transmitted at the first power level, the first station selecting a second power level and transmitting a second power level signal in response to correctly receiving the first frame; and

20 in which the second station transmits the second frame of the first information stream at the second transmitted power level in response to receiving the second power level signal.

35. The system of claim 22 in which the first station is a base station and the second station is a mobile unit.

36. The system of claim 22 in which the first station is a mobile unit and the second station is a base station.

25 37. In a code division multiple access (CDMA) system, a receiving station to accept data burst communications comprising:

a port to transmit and receive messages;

a receiver connected to the port to receive a first information stream including a plurality of data frames transmitted at a first power level;

30 a controller to select a second power level in response to correctly received data frames; and

a transmitter connected to the port to transmit a second power level signal representing the value of the second power level.

38. The receiving station of claim 37 in which the receiver iteratively receives the first information stream at a selected second power level;

5 in which the controller iteratively reselects a second power level in response to correctly received frames; and

in which the transmitter iteratively transmits a reselected second power level signal in response to the reselected second power levels.

39. The receiving station of claim 38 further comprising:

10 a cache for saving correctly received frames, the cache accepting correctly received frames that are not already saved in the cache; and

in which the controller selects the second power level in response to the accumulation of correctly received frames saved in the frame cache.

40. The receiving station of claim 39 in which the receiver measures the 15 number of n frames in the first information stream;

in which the controller compares the number of n frames in the first information stream to the number of k correctly received frames saved in the cache.

41. The receiving station of claim 40 in which the controller finds the effective 20 message length of m frames remaining to be received, where $m = (n - k)$, and decreases the second power level as the number of m frames decreases.

42. The receiving station of claim 41 wherein the first information stream of n frames is a message, in which the controller selects a target message error rate (MER), calculates the target frame error rate (FER) in response to the MER and the effective message length, and calculates a target signal to noise (S/N) threshold in response to the 25 FER.

43. The receiving station of claim 42 in which the controller, following the calculation of the target S/N, modifies the target S/N in response to whether the previous frame was correctly received.

44. The receiving station of claim 42 in which the controller, following the calculation of the target S/N, modifies the target S/N in response to whether the previous frame was saved.

45. The receiving station of claim 42 in which the controller particularly identifies the m frames not saved in cache;

5 in which the transmitter transmits a signal identifying the m frames not saved in cache; and

in which the receiver accepts the first information stream, consisting of the m frames not saved in cache, at the selected second power level.

10 46. The receiving station of claim 42 in which the receiver measures the S/N of the first information stream, compares the measured S/N to the target S/N; and

in which the controller calculates the second power level in response to the S/N comparison in the receiver.

15 47. The receiving station of claim 46 in which the receiver iteratively compares the measured S/N to the target S/N;

in which the controller iteratively adjusts the second power level in response to the S/N comparison;

in which the transmitter iteratively transmits the adjusted second power level signal; and

20 in which the receiver iteratively receives the first information stream at the iteratively adjusted second power level.

48. The receiving station of claim 37 in which controller estimates the number of frames in the first information stream, and selects the first power level in response to the estimate;

25 in which the transmitter transmits a first power level signal;

representing the first power level; and

in which the receiver receives the first information stream at the first power level in response to transmitting the first power level signal.

30 49. The receiving station of claim 37 in which the receiver receives a first information stream of consecutive frames including a first frame followed by a second frame;

in which the receiver receives the first frame transmitted at the first power level;

in which the controller selects a second power level in response to receiving the first frame correctly;

in which the transmitter transmits a second power level signal; and

in which the receiver receives the second frame of the first information stream at 5 the second transmitted power level.

50. In a code division multiple access (CDMA) system, a transmitting station to transmit data bursts comprising:

a port to transmit and receive messages;

a transmitter connected to the port to transmit a first information stream including a 10 plurality of data frames at a first power level;

a receiver connected to the port to receive the second power level signal in response to the number of correctly communicated first information stream data frames; and

in which the transmitter transmits the first information stream at the second power 15 level in response to receiving the second power level signal.

51. The transmitting station of claim 50 in which the receiver iteratively receives power level signals to reselect the second power level in response to the number of correctly communicated frames; and

in which the transmitter iteratively transmits the first information stream at a 20 reselected second power level.

52. The transmitting station of claim 50 in which the transmitter transmits a first information stream of consecutive frames including a first frame followed by a second frame;

in which the receiver receives the second power level signal in response to first 25 frame being correctly received; and

in which the transmitter transmits the second frame at the second power level in response to receiving the second power level signal.

53. The transmitting station of claim 51 in which the receiver accepts a signal which identifies the frames in the first information stream that were not correctly 30 communicated; and

in which the transmitter transmits the first information stream consisting of the frames not correctly communicated.

01/07

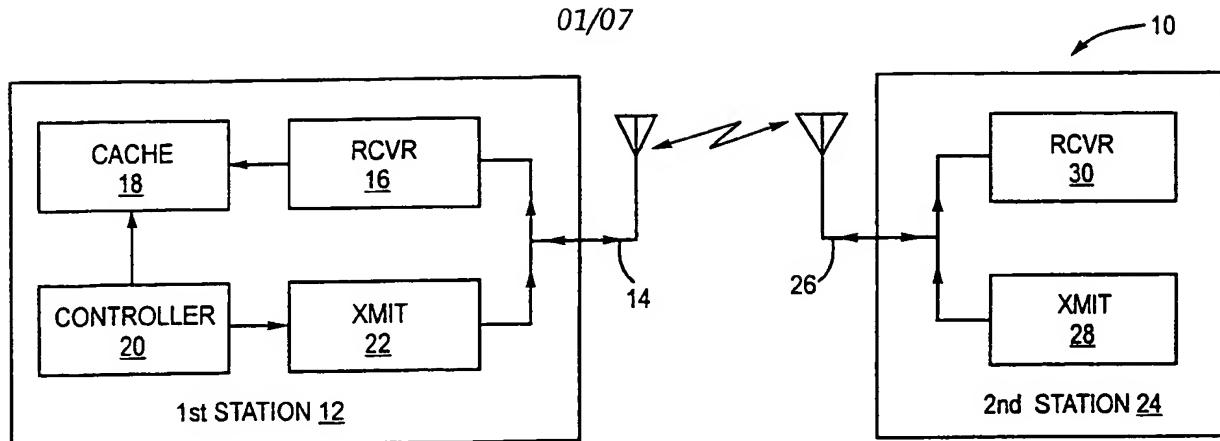


Fig. 1

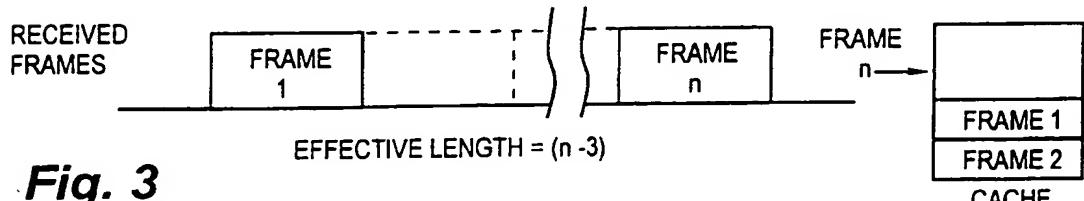
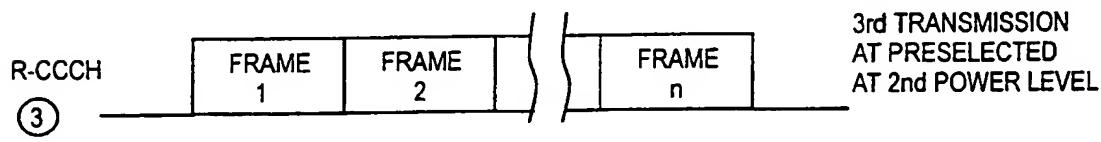
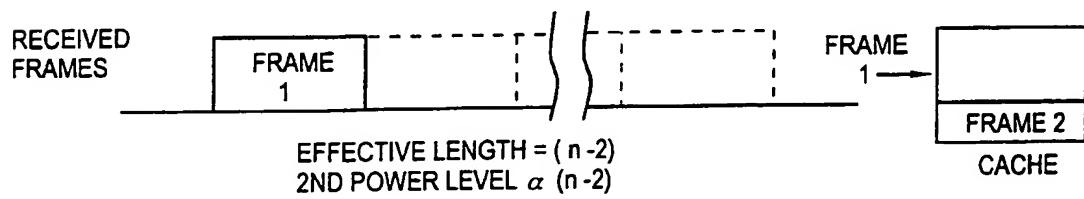
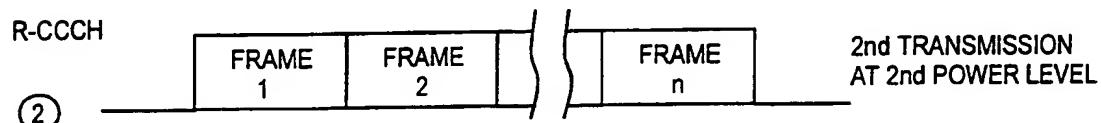
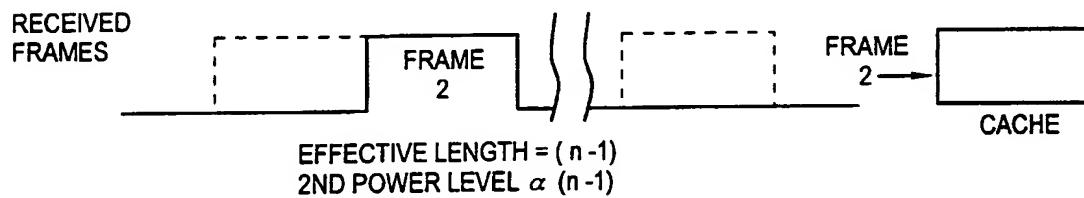
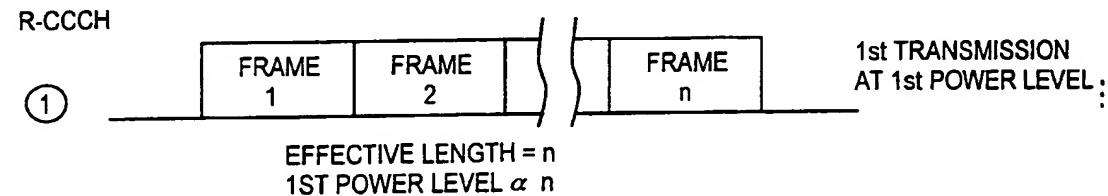


Fig. 3

02/07

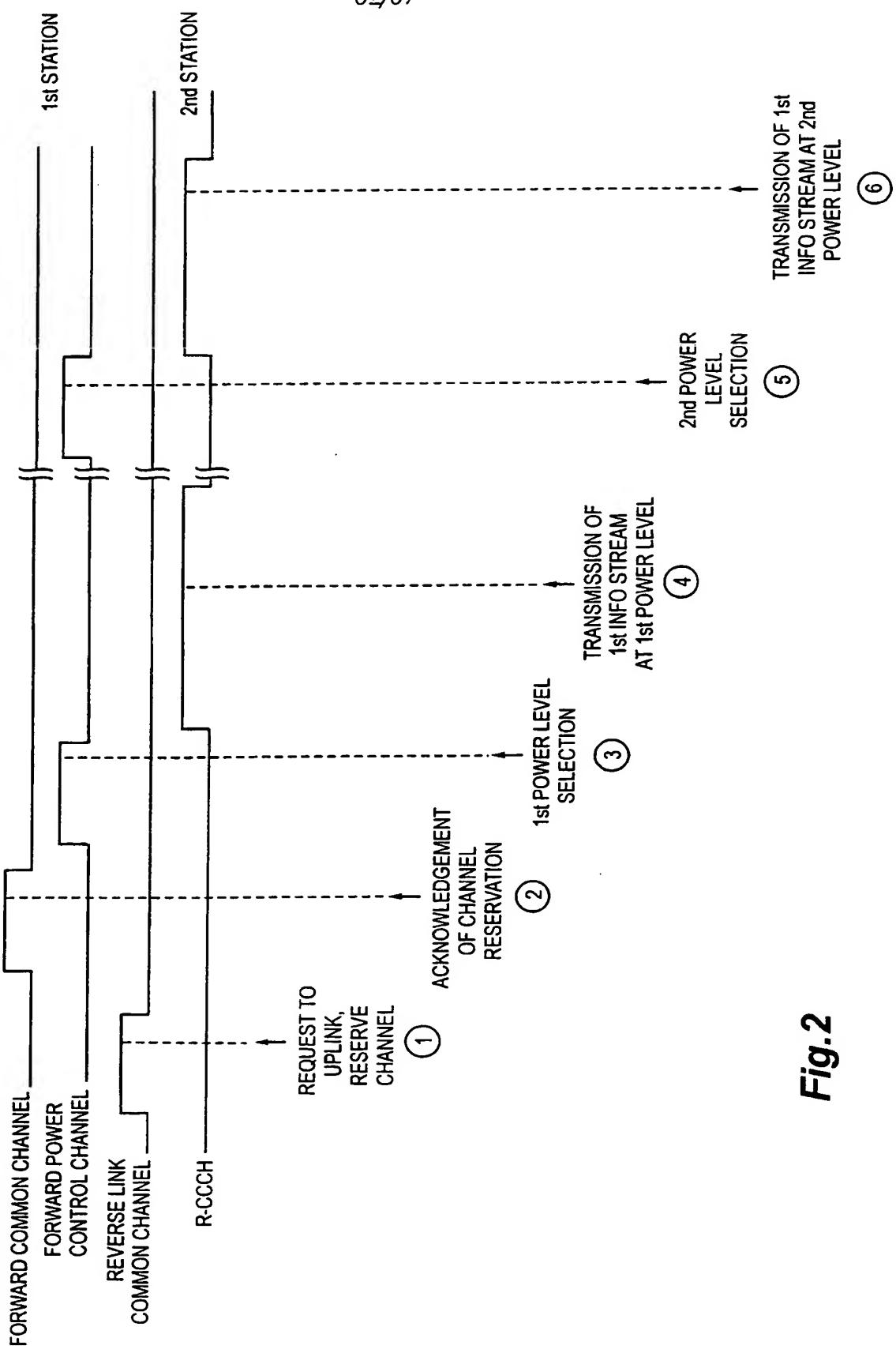


Fig. 2

03/07

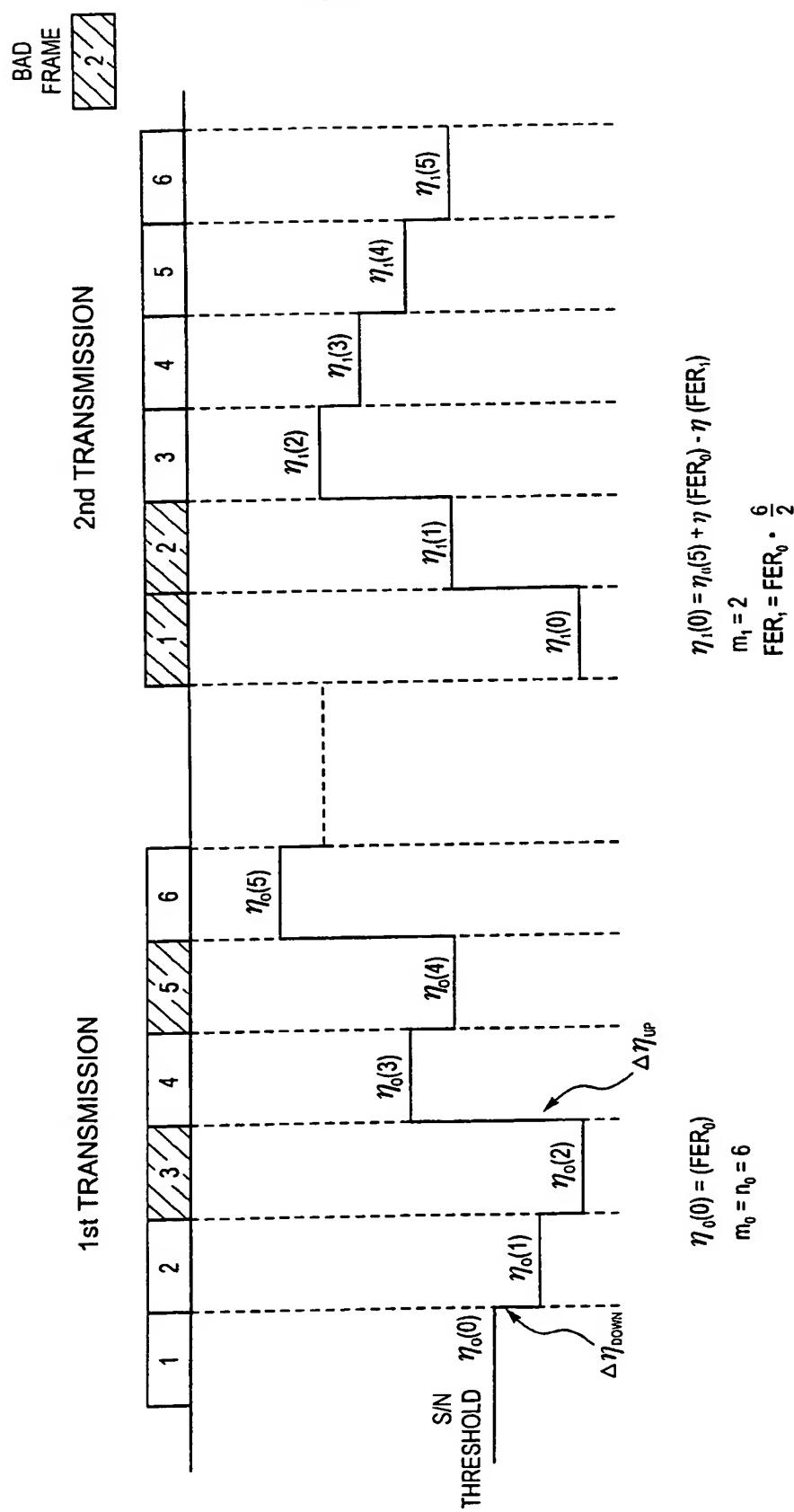


Fig. 4a

04/07

1st TRANSMISSION

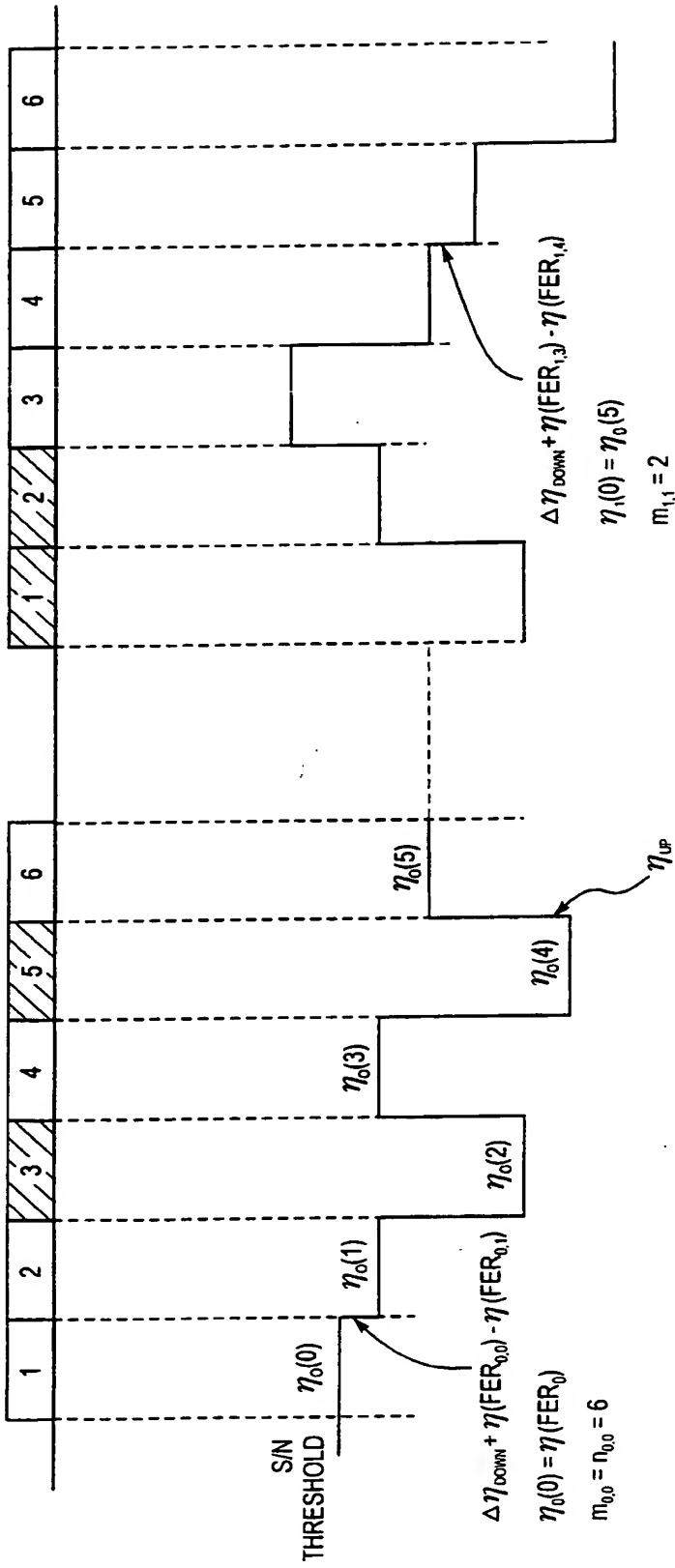
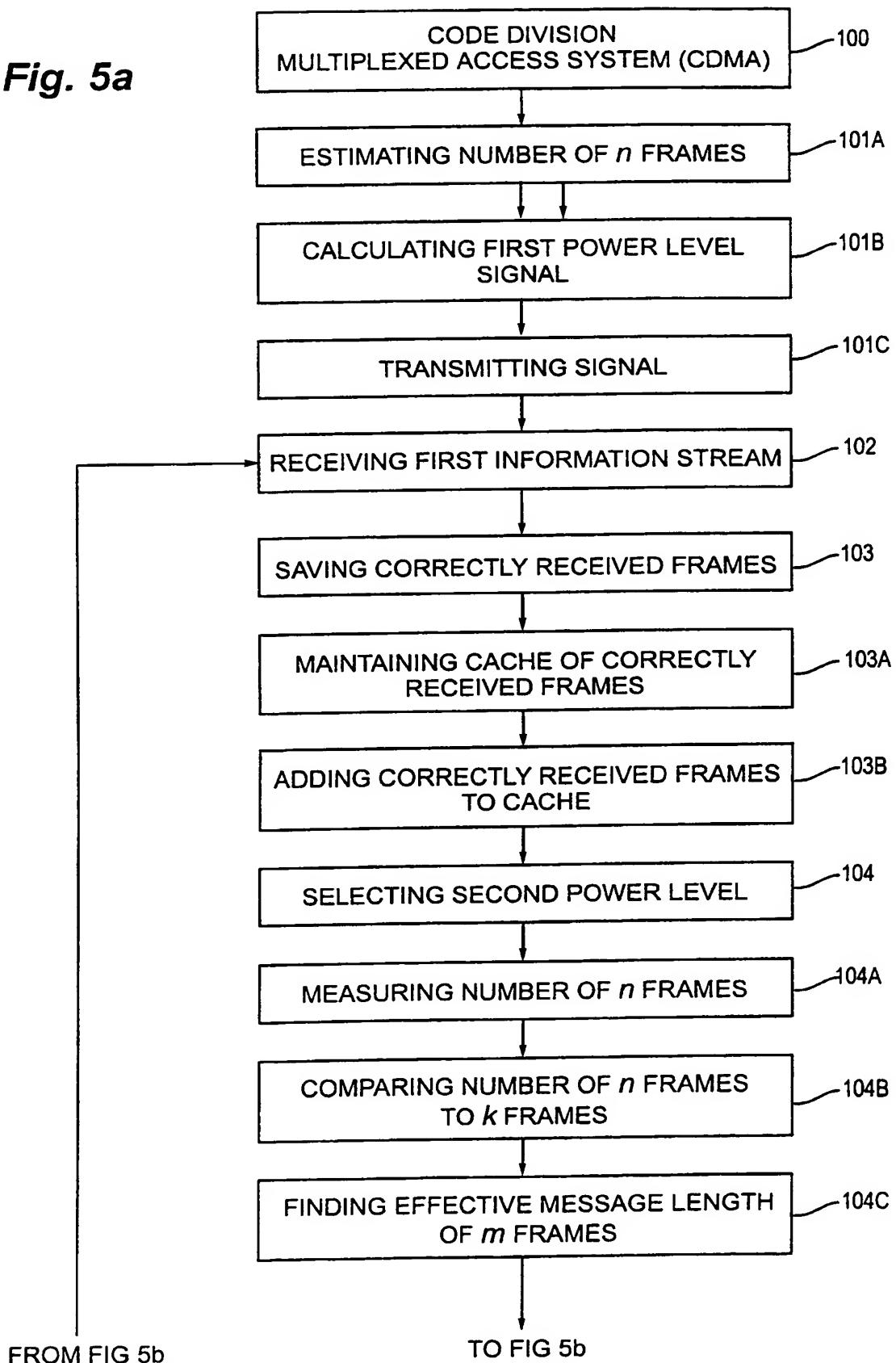


Fig. 4b

05/07

Fig. 5a

FROM FIG 5b

TO FIG 5b

06/07

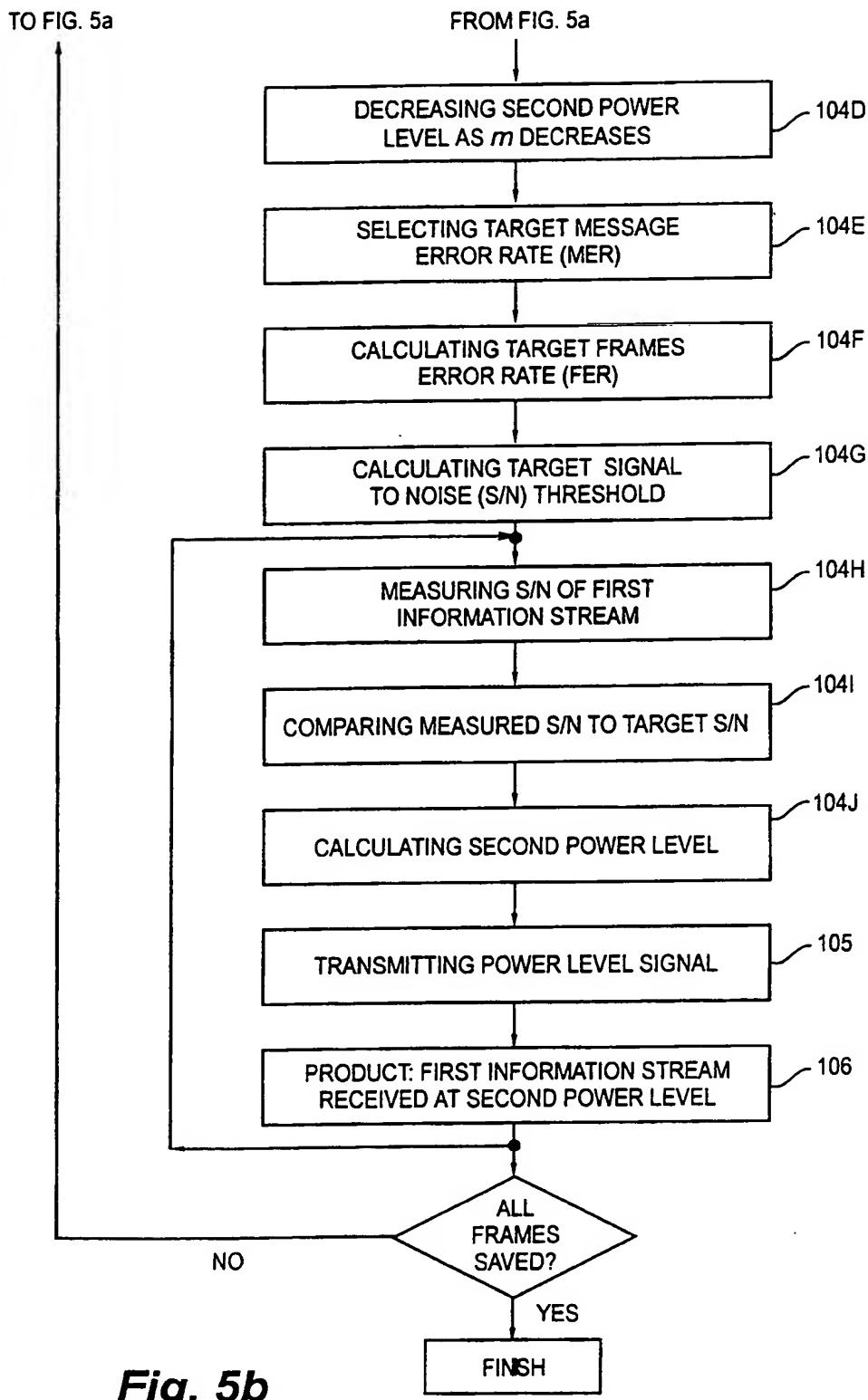


Fig. 5b

07/07

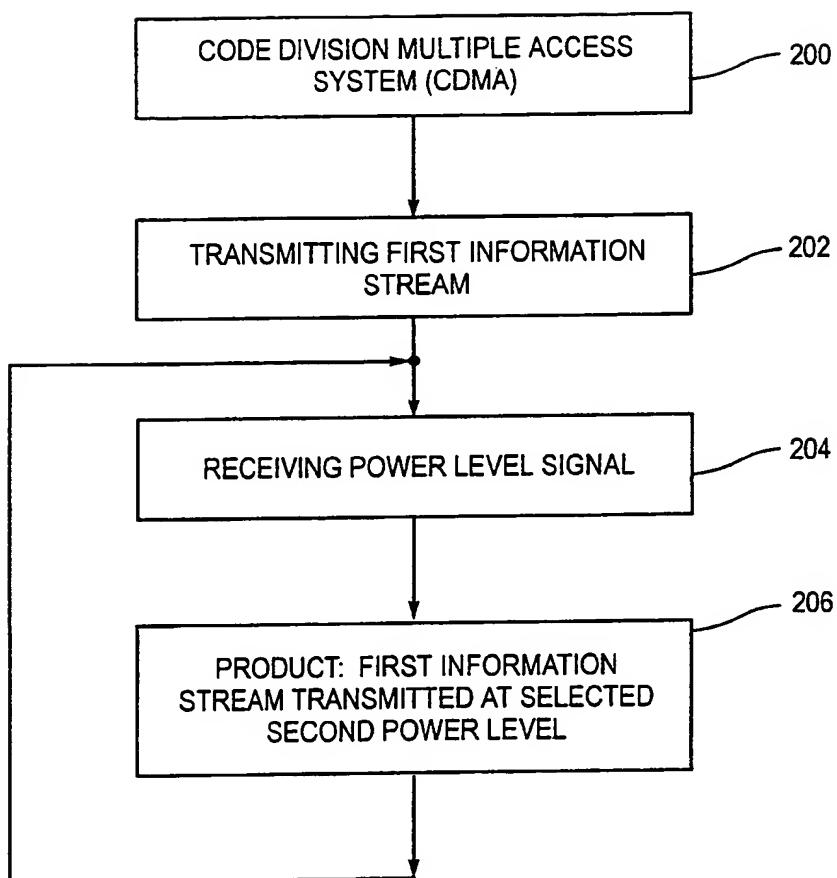


Fig. 6